REPORT MD07

MD07/1.0 INTRODUCTION

This report describes the models of test 2 (Plane frame test) using elastic-plastic shell elements to represent the heated beams and beam general section elements for the in-plane properties of the concrete slab. A schematic view of the heated primary beams in the test are given in Figure MD07/ A model of a 2D slice through the building was considered adequate to model this test as only a very narrow strip of slab was heated either side of the heated primary beams.. Beam elements were used to represent the unheated columns which were unprotected from 200mm from the underside of the deepest bottom flange. This report compares model results to the test. A description of the model is provided.

MD07/2.0 MODEL DEVELOPMENT

The models developed were an attempt to examine the local buckling behaviour of the beams when more than one beam is heated. ABAQUS/Standard [1] was used to analyse the structure consisting of 2 noded beams for the in-plane slaband columns and 4 noded shell elements for the heated beams. Advantage was taken of symmetry at the middle of the 610 deep primary beam so only one half of the slice through the structure was included (Figure MD07/2.01 The columns extended to the floor levels above and below and represented using beam elements, which was sufficient, as they were mostly protected in the test.

Composite Action

Constraint equations incorporated between the slab and beams accounted for shear studs giving full composite action (Figure MD07/2.02). The beam slab elements were located within the top 70 mm of the concrete slab. Beams were connected to columns using a mixture of constraint equations, spring and gap elements to represent connection behaviour. The models were analysed with a gap representing the bottom flange separation from the column flange equal to the thickness of the partial depth endplate and no gap. The slab beam elements were connected to columns at the edge of the building to simulate the restraint from the slab being tied into the column via connection to the edge beams framing into the external column. Representing the slab and beams as described above was necessary to capture correct conditions given by:

- Simplified load transfer of the slab and composite beam
- Local buckling effects of the heated beam
- Stiffness of supporting structure (lateral, vertical and torsional).

Material Model Representation

Beam general sections were used for the grillage representation of the slab. Axial force v strain and moment v curvature properties defined the material behaviour (Figure MD07/2.03). The steel was modelled using an elasto-plastic model with a von Mises yield criterion and using a plastic associated flow rule. Full degradation of the stress-strain curves with temperature was incorporated using nonlinear properties with temperature. Analyses were carried out using both isothermal and an-isothermal material models, namely EC1: Part 1-2 [2] and the Anderburg model [3] respectively. These were applied to both the primary (S355 grade steel) and secondary beams (S275 grade steel). It was found that due to the steeper gradient of stress temperature curves found with the Anderburg material model, this proved to be more stable at temperature above 350^0C. Both material models are illustrated in figure MD07/2.04. The unheated columns were given linear elastic properties.

Loading and Boundary Conditions

Temperature loading applied to the heated area was taken from measured values of each member in the test (Figure MD07/2.05). However, the actual temperature profile through the slab is less uniform. Slab temperatures were inputted at the reference axis with a constant thermal gradient. The effect of this approximation was reported in heat transfer analyses (Appendix HT1-2).

The boundary conditions consisted of fixing the column ends at the floor level below the heated floor and horizontally restraining the column ends at the floor level above. Since a model representing half the structure was adequate the cut edge was restrained from moving in-plane, thus mirroring the restraint provided by the remaining heated structure (Figure MD07/2.06).

MD07/3.0 DISCUSSION OF RESULTS

The shell representations of the heated beams, which aimed at capturing local buckling effects, showed very good agreement with the temperature-deflection profiles of the heated beams (Figure MD07/3.0). Deflection is thus caused primarily by action of the heated beam. The effect of the gap element between the bottom flange and the column can be said to be negligible.

MD07/4.0 CONCLUSIONS

Agreement between the model and test results provides a reasonable level of confidence in the modeling of primary beams. The effect of connection modeling has an effect early in the test but has negligible effect on behaviour in the later stages of loading. This is because expansion of the heated beams tends to push the connections back into the columns.

MD07/5.0 REFERENCES

1 Hibbitt, Karlsson & Sorensen, Inc., *'ABAQUS Theory Manual'* v5.8, HKS Inc., 1080 Main Street Pawtucket, RI 02860-4847 USA.

2 ENV 1993-1-2:1985: *'Eurocode 3 – Design of Steel Structures'*, Part 1-2: General Rules – Structural Fire Design.

3 Practical Design Tools for Composite Steel-Concrete Construction Elements Submitted to ISO-Fire Considering the Interaction Between Axial Load N and Bending Moment M, Commission of the European Communities Technical Steel Research, France 1991.

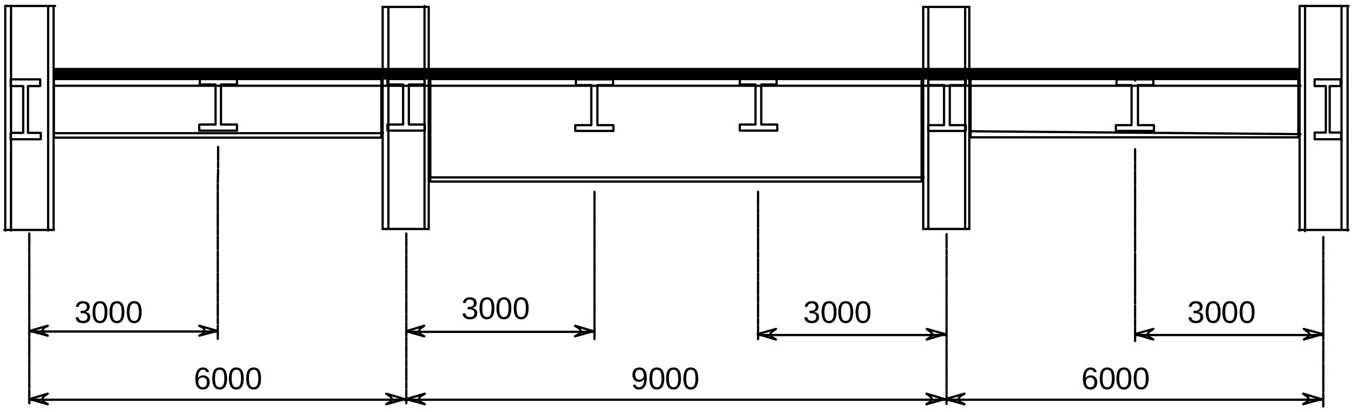


Figure MD07/1.01: Schematic of heated beams in the plane frame test.

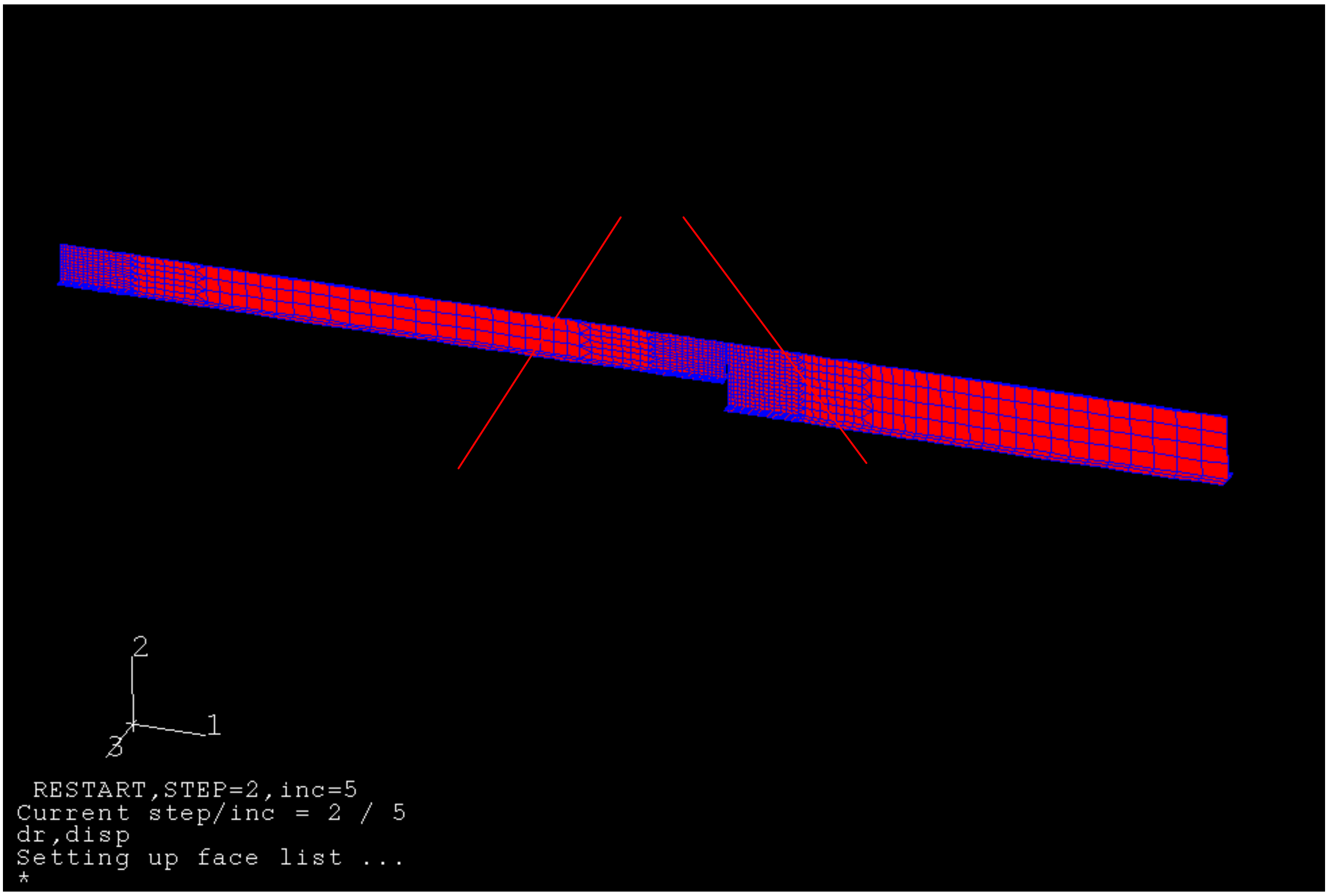
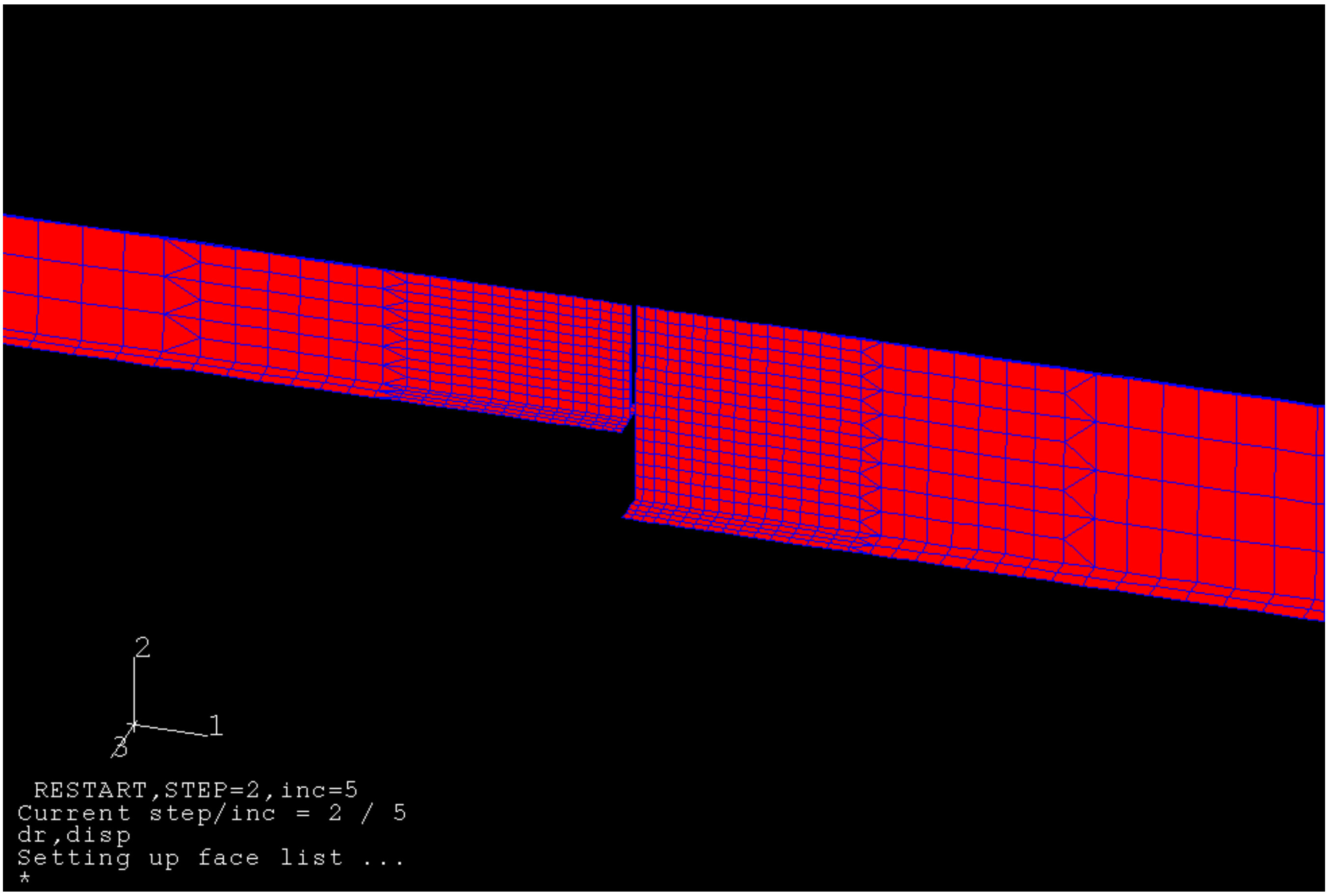
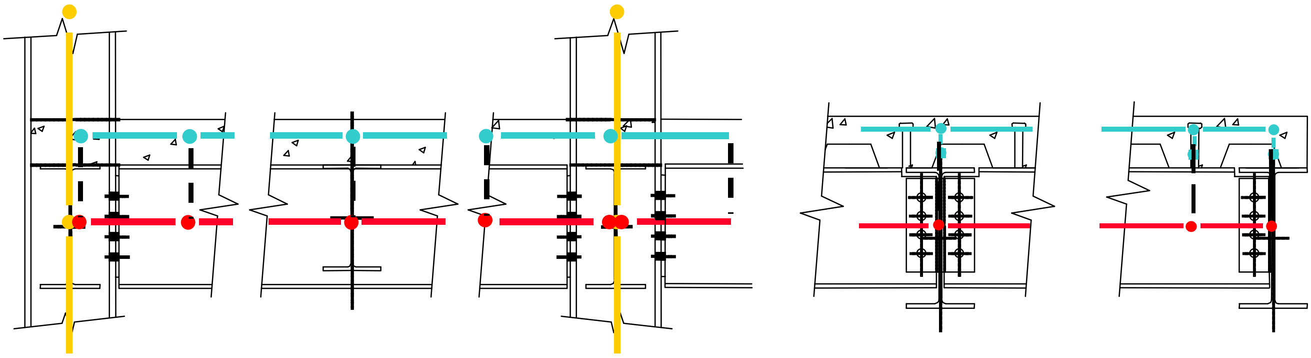


Figure MD07/2.01:Discretisation of half of the plane frame test

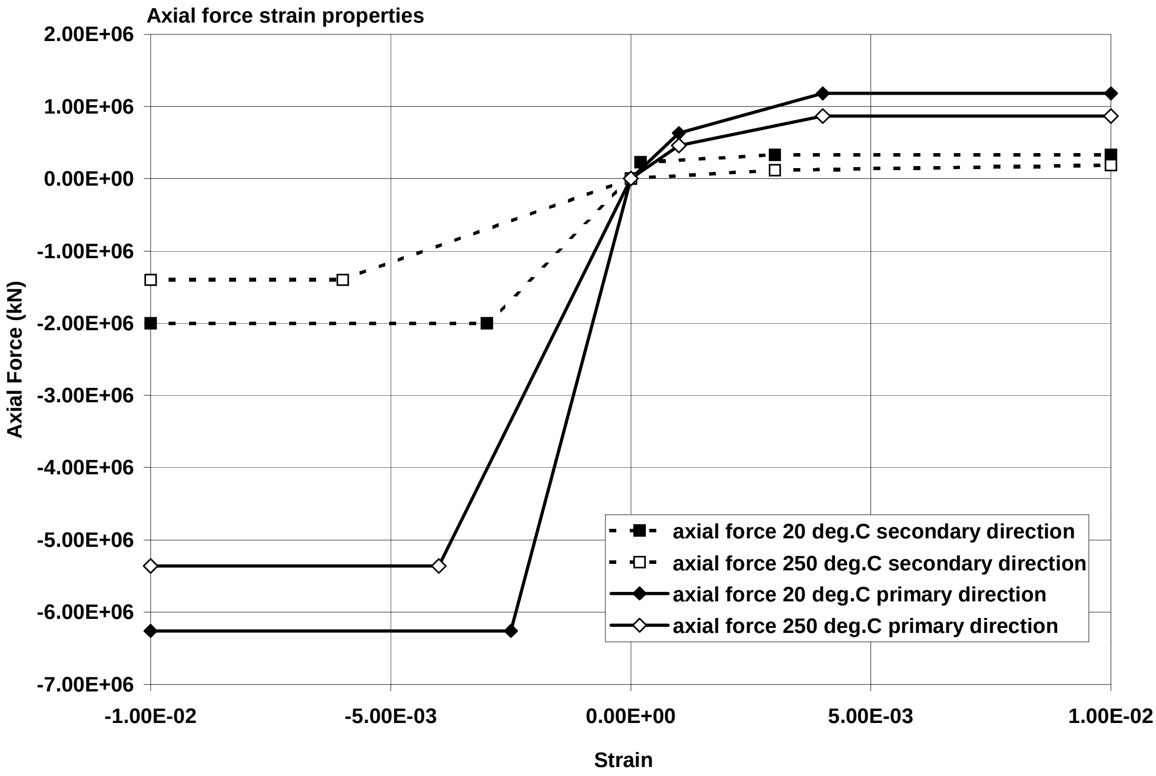


(a): Shell representation of heated beams at column connection



(b): Slab and beam discretisation

Figure MD07/2.02: Modelling of composite arrangement



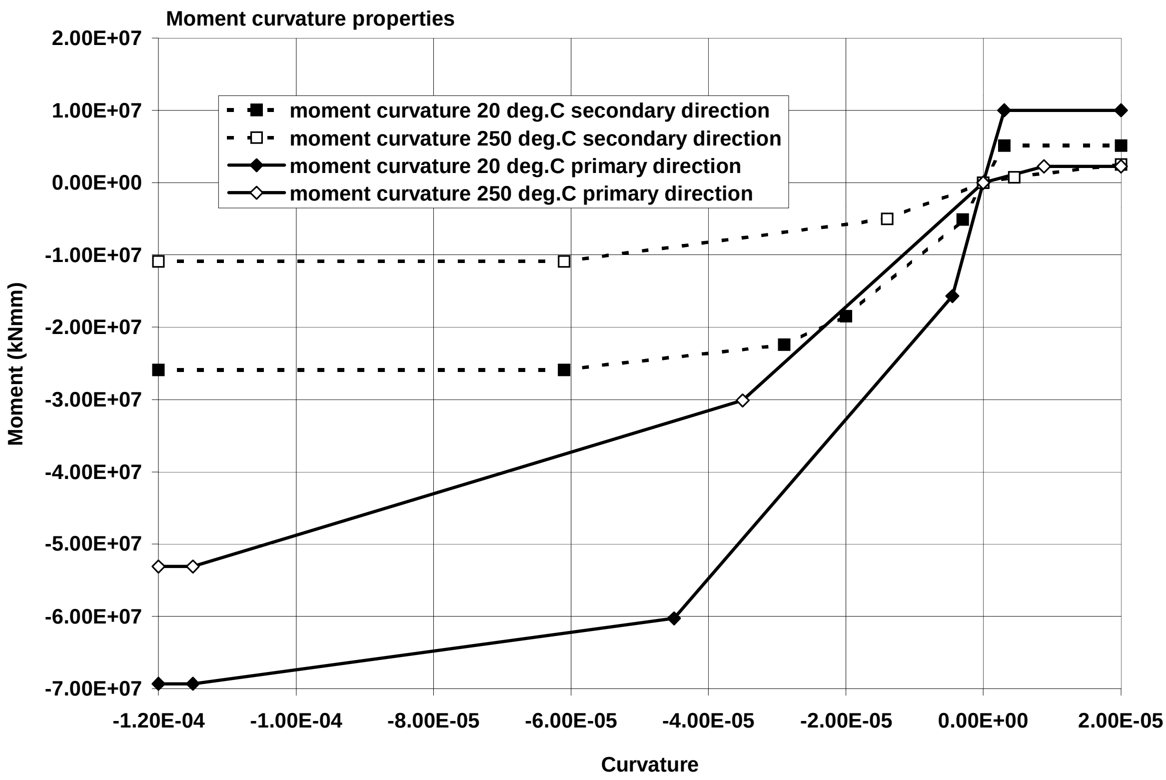
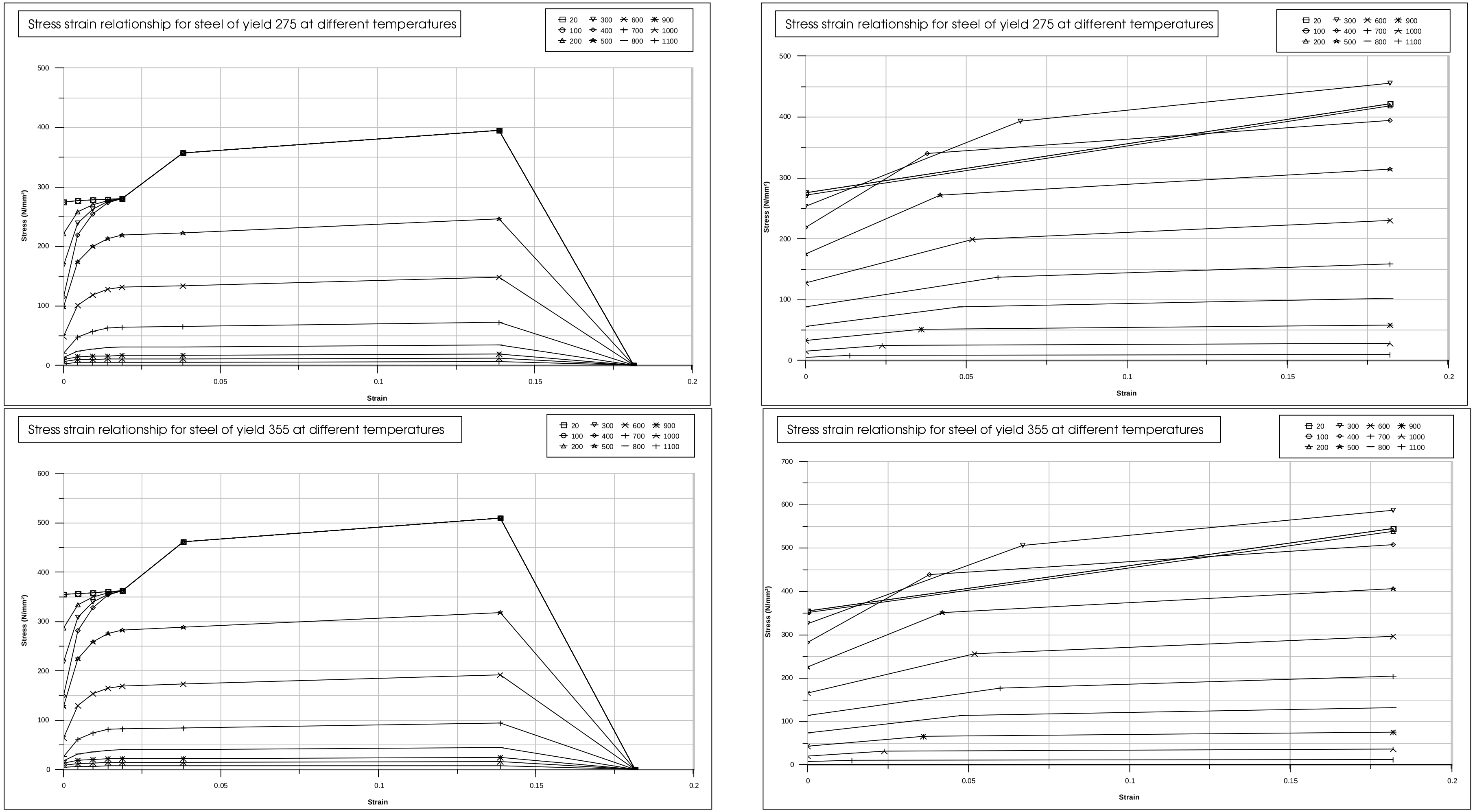


Figure MD07/2.03: Material behaviour of beam general sections representing the grillage slab



(a): EC 3 pt.1 stress strain relationship

(b): Anderburg stress strain relationship

Figure MD07/2.04: Stress strain relationship for grade 275 and 355 steel with increasing temperatures

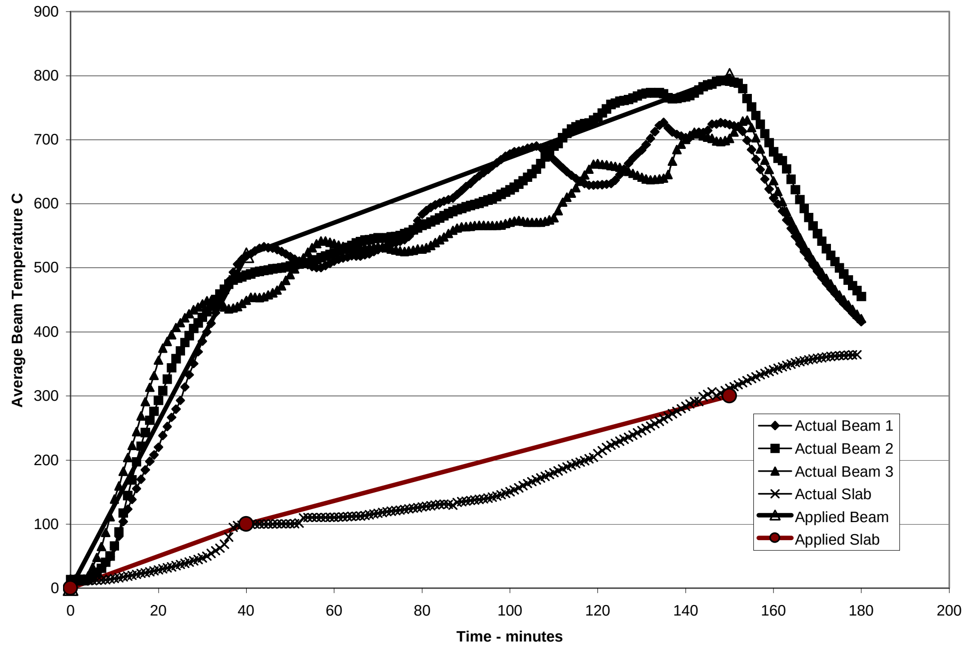
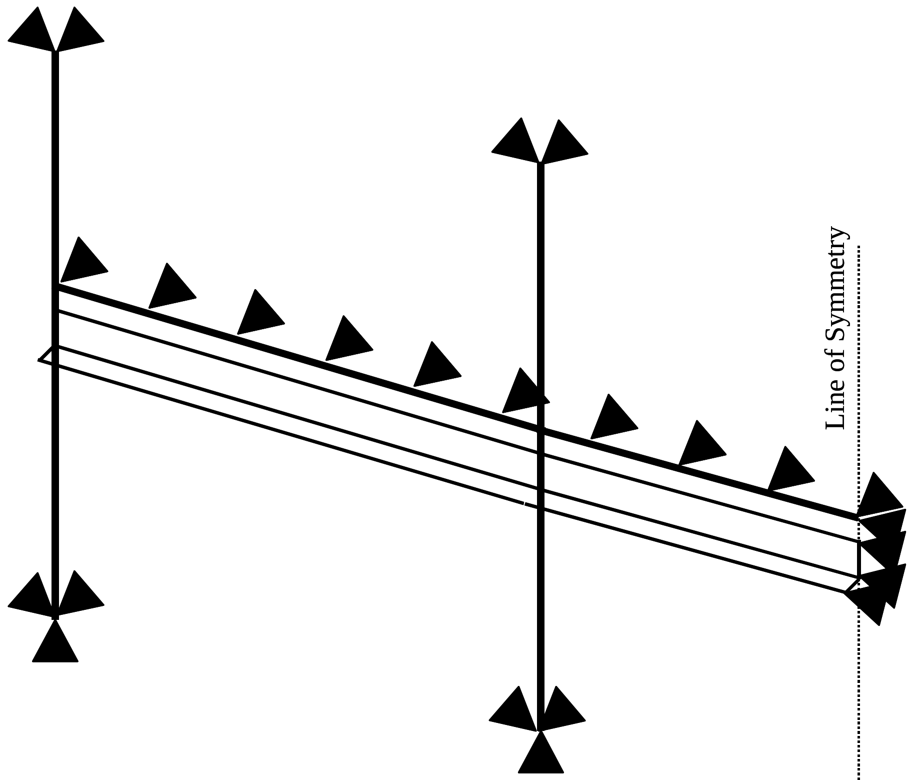
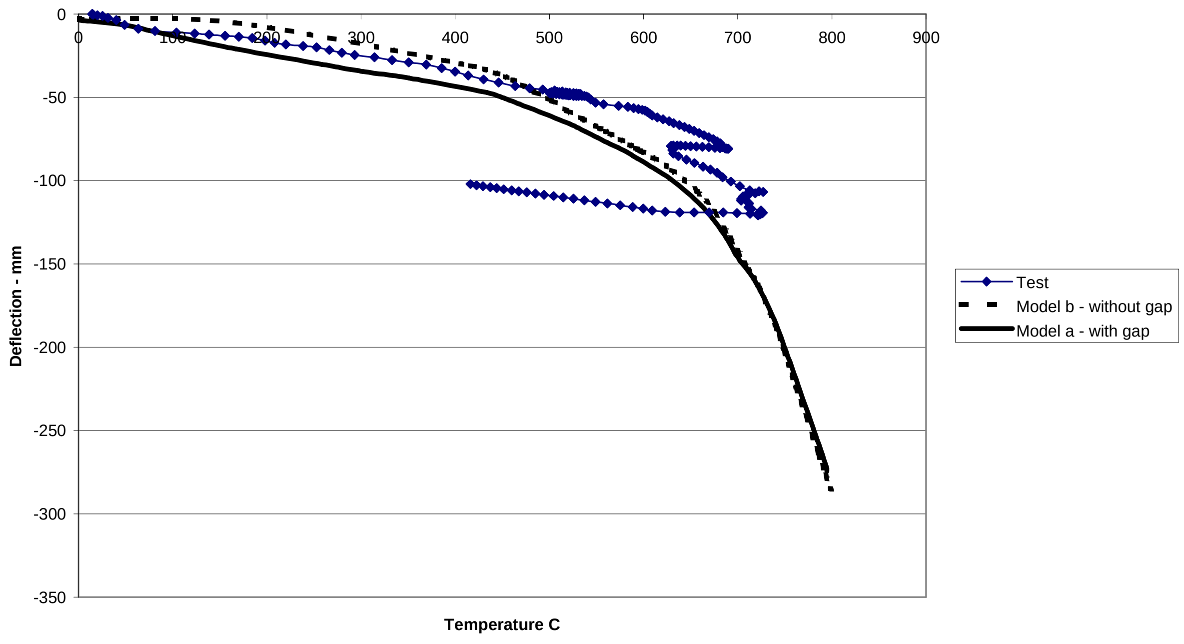


Figure MD07/2.05: Temperature load curves applied to beams and slab



MD07/2.06: Model boundary conditions

Temperature-Deflection - Test 2 - 356UB Primary beam



Temperature-Deflection - Test 2 - 610UB Primary beam

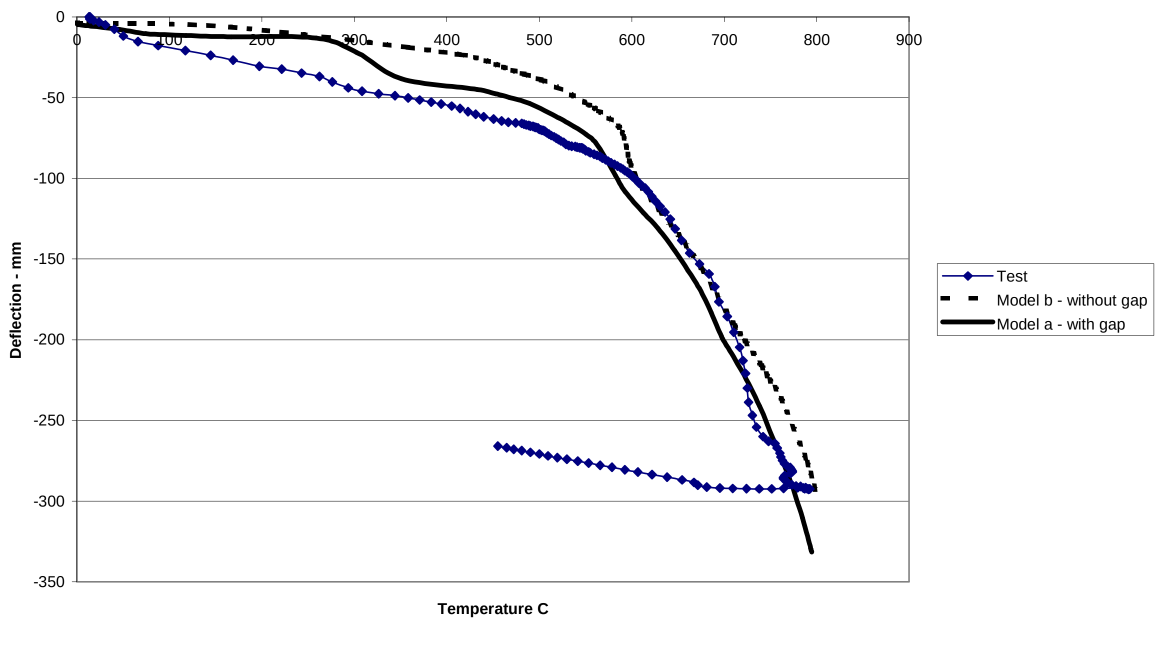


Figure MD07/3.0: Comparison of Beam Central Deflections